

New Results on the Ages of Star Clusters in Region B of M82

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Abstract The post-starburst region B in M82 and its massive star cluster component have been the focus of multiple studies, with reports that there is a large population of coeval clusters of age ~ 1 Gyr, which were created with a Gaussian initial mass distribution. This is in disagreement with other studies of young star clusters, which invariably find a featureless power-law mass distribution. Here, we present Gemini-North optical spectra of seven star clusters in M82-B and show that their ages are all between 10 and 300 Myr (a factor of 3-100 younger than previous photometric results) and that their extinctions range between near-zero and 4 mag (A_V). Using new *HST ACS-HRC U*-band observations we age date an additional ~ 30 clusters whose ages/extinctions agree well with those determined from spectroscopy. Completeness tests show that the reported ‘turn-over’ in the luminosity/mass distributions is most likely an artefact, due to the resolved nature of the clusters. We also show that the radial velocities of the clusters are inconsistent with them belonging to a bound region.

1 Introduction

Region B, in the local starburst galaxy M82, has been the object of debate in recent years, due to claims that it hosts a 1 Gyr-old, independent starburst region (de Grijs et al. 2001). Furthermore, a turn-over was reported for the cluster mass distribution. This would make it unique among young cluster populations, which are generally accepted (and theoretically expected) to have power-law distributions.

As part of a larger project¹ to study the cluster population of the entire galaxy, we have utilised multi-band (*UBVI*) *HST-ACS* photometry of 35 Young Massive Clusters (YMCs) in the region and additionally, Gemini-North multi-object spectroscopy (GMOS-N) of seven of them, from which we constrain extinctions, ages and radial velocities. We present these results in sections § 2, 3 and 4 and a summary and conclusions in § 5.

2 Estimating the extinction

The clusters in region B have been presented in the past as having very low extinctions (de Grijs et al. 2003). Coupled with the claim that the region has a very high gas/dust extinction gradient, it was suggested that only the outermost layers of the region are visible.

Using the three-dimensional maximum likelihood fitting photometric technique (3DEF, Bik et al. 2003), and reddening maps in some cases, we find that the 35 clusters in our photometric sample have extinctions between near zero and ~ 2.5 mags (in A_V , after foreground

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¹We refer the reader to Smith et al. (2007, multi-band photometry) and Konstantopoulos et al. (2008a, spectroscopy) for full details of source selection, data acquisition, reduction and analysis, and full spectroscopic and photometric results.

extinction correction). We also find pronounced effects of differential extinction across the face of some clusters (see Figure. 1). While this leaves the spectroscopically measured properties unaffected, it complicates the measurement of cluster colours, and consequently, the photometric age determination.

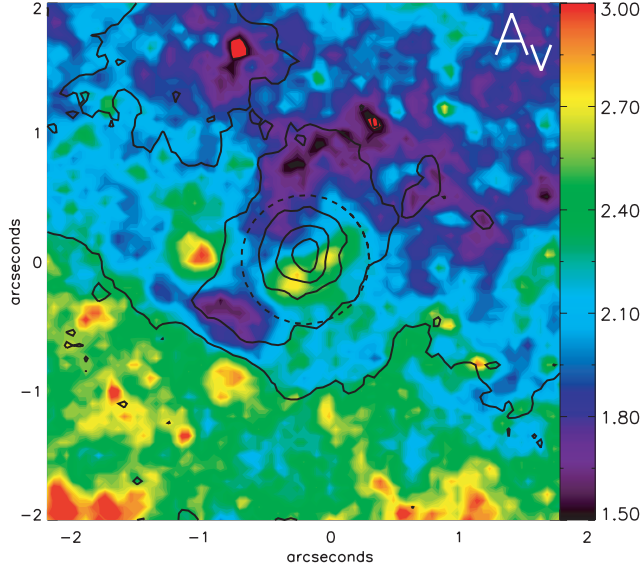


Fig. 1 Extinction map for cluster 91 (M82-H). The extinction is calculated for each pixel using the available *BVI* photometry (given an accurate spectroscopic age of 190 Myr). The solid lines represent isophotes in the F435W-band (*V*) and the dotted circle denotes the aperture used for the cluster photometry. The colour map gives the extinction in magnitudes. The spatial scale of the map is 30×30 pc. Note the strong dust lane running across the cluster, strongly influencing the photometry and photometrically derived values, such as age and extinction.

The measured range of extinctions establishes region B as one of the overall least obscured parts of the M82 disk, however, it does not necessarily imply that all visible clusters are on the surface. Our data offer the interpretation that region B presents a view deep into the body of the galaxy through a series of low extinction ‘portholes’, similar to “Baade’s windows” in the Milky Way. As a result of this, a greater number of clusters can be seen in region B compared to the rest of the disk. This large number of clusters should not be treated as an intrinsic property for this part of the galaxy (such as evidence of a higher SFR in the region), but as an apparent one. In fact, *HST-NICMOS* near infrared observations of the galaxy (Alonso-Herrero et al. 2001, 2003) show similar luminosities and cluster densities in both galaxy lobes.

3 Age determination

We use a number of independent photometric and spectroscopic methods in order to obtain the best possible age estimate for each cluster. All of these methods are based on the use of models and the goodness of fit between observation and model.

As a first estimate, we determine the ages from the comparison of *UBVI* magnitudes to cluster evolutionary synthesis models (GALEV models, Anders et al. 2005), using the 3DEF method (demonstrated in Figure. 2). We then proceed to test these against two independent spectroscopic methods.

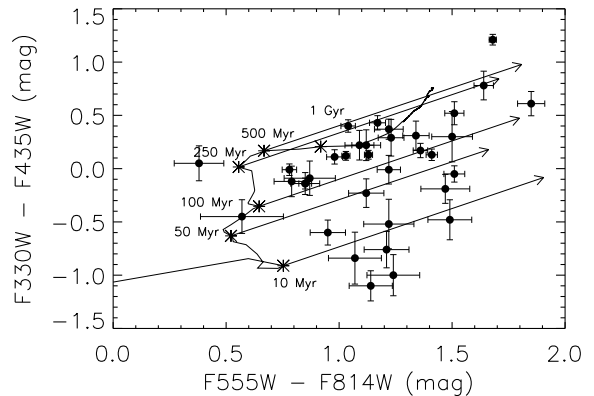


Fig. 2 $U - B$ vs $V - I$ plot for all 35 *U*-band selected clusters (this includes six of seven clusters for which we have spectra). The extinction vector has length $A_V = 3$ mag. The cluster that falls outside the evolutionary track (cluster M82-H, presented in Figure. 1) has an underestimated *U*-band flux.

The more important of these methods is χ^2 fitting of lower Balmer series lines ($H\beta$ and $H\gamma$) with models, specifically designed for young stellar clusters (González-Delgado et al. 2005). We refer to this method as the cumulative χ^2 method (CCM) and it is demonstrated in Figure. 3 for a randomly selected cluster. Its advantage is that it fits on the overall profile shape, rather than just on the line strength (like the simpler employed model-spectrum residual method, or MSRM). In all, we find spectroscopic and photometric methods to be in accord within the calculated errors.

Overall, we find the age distribution of YMCs in region B to peak at ~ 150 Myr, which is much younger than has been claimed in the past (1 Gyr peak in de Grijs et al. 2001, 2003). In addition, we find several of the clusters to have ages similar to M82-F (measured as 60 Myr by Smith and Gallagher 2001), which resides on the opposite side of the galaxy. In Konstantopoulos et al. (2008b) we perform a similar

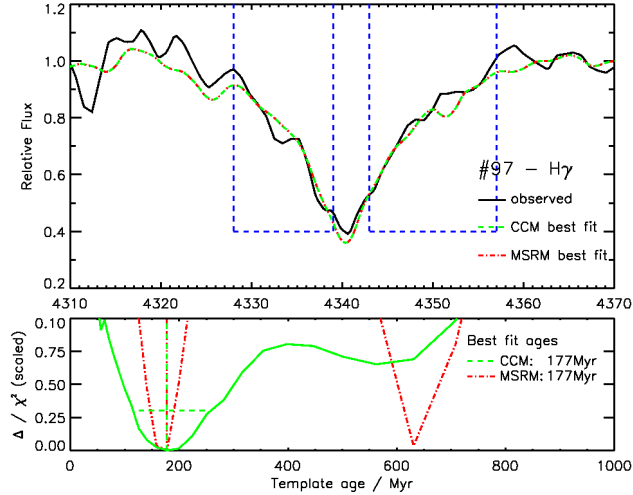


Fig. 3 The spectroscopic age determination routine for cluster 97 ($H\gamma$ line). The bottom panel shows the cumulative χ^2 method (CCM) and model-spectrum residual method (MSRM) statistics in green and red respectively as a function of model age, with the best fits indicated by the vertical lines. The horizontal dashed line indicates the adopted error margin of twice the minimum χ^2 value. The top panel shows the observed spectrum with the best fit model over-plotted.

analysis of the entire galaxy disk population and find the same characteristics for the age distribution of the galaxy. This coincidence of SF peak and spread in measured ages between region B and the full galaxy sample reinforces our suggestion that this region is not ‘special’, but is simply located behind a line of sight of relatively low extinction.

4 Radial Velocities

It has been claimed in the past that region B constitutes a bound region, that moves independently to the rest of the galaxy disk (de Grijs et al. 2001, 2003). In order to gain some insight into this claim, we measure the radial velocities of the seven clusters for which spectroscopy is available, which we then proceed to plot over the rotation curve of the galaxy (see Figure. 4). This enables us to determine whether the clusters move in regular orbits. If the region was bound, the clusters would move in unison (solid body rotation); assuming a constant rotational velocity, the outer boundary of the region would need to move twice as fast as the inner boundary for the clusters to move together.

However, we find region B clusters to lie on the flat part of the curve, indicating that they move along with the bulk of the galaxy. This means that the region

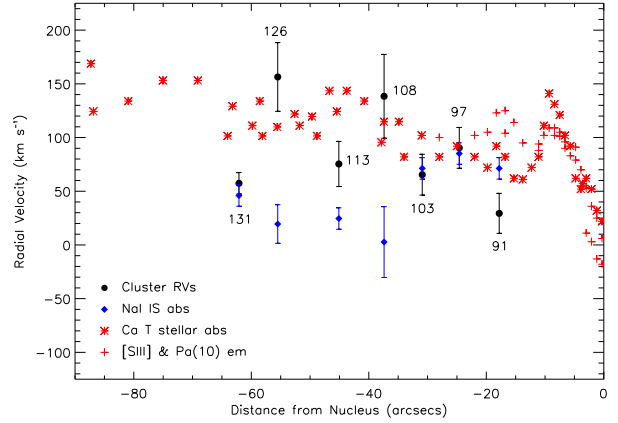


Fig. 4 Correspondence of star cluster velocities with the rotation curve for M82, as derived from infrared observations by McKeith et al. (1993). The cluster velocities appear to be consistent with the flat component of the curve. We also plot the velocities of the gas in the line of sight of the clusters. The distance in velocity-space between the clusters and the line of sight gas indicates the amount of dust and gas between the observer and the cluster. Therefore, this distance may be considered to represent the depth at which the cluster is found, with respect to the galaxy disk surface.

cannot be self-bound, or kinematically independent to the nuclear gravitational well.

5 Conclusions

We have performed a detailed study of the stellar cluster population of M82 region B, using spectroscopy and multi-band photometry, and conclude the following:

- The clusters are considerably younger than previously reported (de Grijs et al. 2003), with ages in the range 10-300 Myr, peaking at 150 Myr. This is in agreement with the 220 Myr timescale for the last encounter with M81, the event that triggered the starburst.
- We find significantly higher extinctions than previous studies, ranging up to $A_V \sim 2.5$ mag. However, the region has a lower overall extinction compared to the rest of the disk, hence allowing a view deep into the body of the galaxy.
- The radial velocities of the clusters follow the galactic rotation curve, indicating that region B cannot be kinematically distinct from the rest of the disk.
- Consideration of the detection limit for resolved clusters shows that the reported turnover in the mass/luminosity distribution of the clusters is caused by incompleteness effects (discussed in Figure. 5).

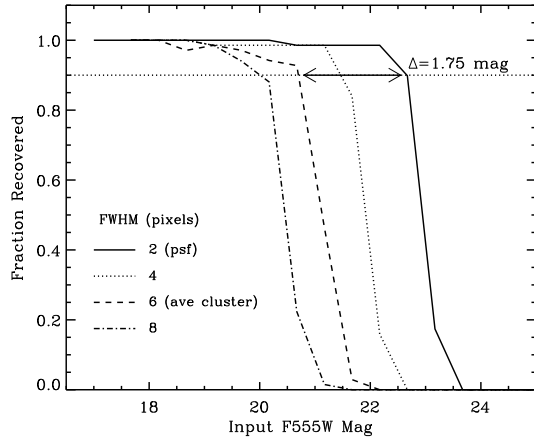


Fig. 5 This plot shows the fraction of input flux recovered from artificial sources of resolved (dotted, dashed and dashed-dotted lines) and unresolved (solid line) nature. The difference in recovered fraction between the average cluster and a point source (6 and 2 pixel FWHM respectively) is 1.75^m ; de Grijs et al. (2003) treated M82 clusters as point sources, however our tests show (as will be presented in Konstantopoulos et al. 2008b) that at the distance of M82 (3.6 Mpc), cluster surface brightness profiles are resolved. This discrepancy leads to a miscalculation of the completeness limit. Correcting for this, we find no evidence for a turnover in the luminosity/mass distribution.

Overall, our findings contradict previous claims that present region B as having formed ~ 1 Gyr ago, during an off-set, independent starburst episode. Our data strongly suggest that region B simply represents a line of sight into the galaxy, allowing a clear view of the cluster population of the disk, which undoubtedly formed during a galaxy-wide starburst.

The results presented here form part of a large spectroscopic study of the star cluster population of M82, which will be presented in Konstantopoulos et al. (2008b, spectroscopy of 61 clusters).

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